The Odyssey of Yuan Tseh Lee: "Should Be All Right"

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It is a privilege and a pleasure to write about Yuan Lee. For me, as for a host of his students and colleagues, Yuan is inspiring for his "beautiful life as a wonderful human being, his dedication to science, his selflessness and idealism," and his earnest devotion to teaching and public service. The words in quotes are from his own description[1] of Madame Curie (with "her" → "his"). As a boy, Yuan read Eve Curie's biography of her mother and decided to become a scientist. I hope that many young people who learn of Yuan's splendid odyssey will likewise decide to pursue science.

A 60th birthday has long been accorded particular honor, especially in Asian traditions. Completing five cycles of the zodiac, it is a time to celebrate mystic harmonies of life, to venerate ancestors, and to think of the generations to come. In service of this tradition, when tracing Yuan's career, it seems apt to emphasize here early portions of his trajectory, including a few special collisions, some fateful, some just fun.[2] These antecedents to his remarkable accomplishments offer much for young scientists to emulate. As in collision dynamics generally, initial conditions are often as important as the forces encountered.

Yuan Tseh Lee was born on November 19, 1936, in Hsinchu, Taiwan, the third of nine children. His father, Tse Fan Lee, was a professional artist, and his mother, Pei Tsai, an elementary school teacher; their ancestors had moved to Taiwan from mainland China in the sixteenth century. When Yuan started school, Taiwan was still under Japanese occupation, and during World War II his family was relocated to the mountains to avoid bombing by Allied Forces. Only after the end of the war was he able to attend classes regularly, in the third grade. He was quite active in sports, becoming a little league champion in Ping-Pong and playing second base in softball.[3] (Much later, he was tempted to try to play professional baseball.) In high school, Yuan was on the tennis team and played the trombone in the band. All along, he was an avid student; on his own initiative he read widely, including many literary works and social science as well as natural science.

Yuan entered the National Taiwan University in 1955, admitted without the usual entrance examination by virtue of his excellent performance in high school. By the end of his freshman year, he had decided to major in chemistry. Under Professor Hua-sheng Cheng, Yuan carried out a research project on the separation of Sr and Ba by paper electrophoresis. He recalls fondly a "free and exciting atmosphere, the dedication of some professors, and camraderie among my fellow students", but also notes conditions were "less than ideal" for studying science.[1] For instance, Yuan once told me that in his student days in Taiwan he had to grind his own stopcocks. Such a start was poetic, for a man destined to construct so many elegant and intricate scientific instruments; it also links Yuan to Galileo and Newton, who ground their own lenses to make telescopes.

After receiving his B.Sc. degree in 1959, Yuan undertook graduate study at the National Tsinghua University. Under Professor H. Hamaguchi, he determined the radioisotopic composition of a mineral found in hot spring sediments, completing his M.S. degree in 1961. He continued another year with Professor C. H. Wong, conducting X-ray structure determinations as a research assistant.

In 1960 Kenneth Pitzer from Berkeley visited Taiwan to give a series of lectures, providing Yuan his first opportunity to meet a professor from the West. Although just a first-year graduate student, Yuan was asked to prepare, from audio tapes, translations of the lectures for publication in the *Journal of the Chinese Chemical Society*. This was an arduous task, since his English then was spotty; he recalls that in trying to decipher some words and phrases, he had to replay the tape so often that it would break from wear. Engaged in such linguistic grinding, he did not dream that someday his own lectures would be translated into many languages.

In 1962, having decided to come to the United States for further graduate study, Yuan enlisted help in sounding out possibilities. His older brother, Yuan Chuan, then pursing a Ph.D. in biochemistry at the University of Iowa, wrote to Berkeley asking about prospects if Yuan Tseh applied. The response was discouraging; it said, emphatically, that Berkeley had no way to evaluate a foreign student applicant. However, Professor Wong, who had done his Ph.D. at Caltech, wrote to Leo Brewer at Berkeley, testifying that Yuan was as good as Caltech graduate students Wong had known. Highly respected both as a scientist and as a keen judge of talent, Brewer interceded to good effect, and Yuan was admitted to Berkeley.

Blossoming at Berkeley. Early that fall, Yuan came to my office to ask if he could join my research group. What ensued was a misunderstanding, but with lucky consequences. Then and since my policy was to accept any student who wanted to work with me, but only after they have a clear idea about difficulties as well as optimistic prospects. Also, I want the student to choose their own project. My approach is to describe several possiblities, offer my assessments of pros and cons, but not tell anyone what to do. Habitually I say, "You might want to consider ...." Although the year before my group had nice success with crossed molecular beam studies of alkali atom reactions with alkyl iodides, since then we'd had a miserable time trying other halogen compounds that poisoned our surface ionization detector. When Yuan came, I told him of these frustrations and suggested he might want to consider a safer project, involving microwave spectra of a beam rather than reaction. It was easy for him to miscontrue that, and he showed good judgment in joining instead Bruce Mahan's group.

However, the next year Yuan took my quantum mechanics course and also a seminar course I gave for the first time on molecular collision theory. It was also the last course I taught at Berkeley, as my group moved to Harvard that fall. The quantum course was the first taught in the Pitzer Auditorium of Latimar Hall, which was still under construction and the lighting was not fully installed. This led to an episode that Yuan told me aided his linguistic education. Because of the dim light, we kept the side doors open. A dog wandered in that had a markedly bent tail. I'd been talking about perturbations, a word Yuan did not know. He said it became immediately clear when I pointed out that the dog's tail must have suffered a perturbation.

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Yuan made very rapid progress in his thesis project with Mahan, a study of the chemionization of excited alkali atoms. In particular, their results confirmed that when an electron is removed from an alkali dimer molecule, the bond gets longer but stronger. This blatantly contradicts simple molecular orbital theory, in which removal of a bonding electron should make the bond longer and weaker. Soon after hearing of Yuan's results, I happened to be in the company of a distinguished theorist. He had just given a seminar at Harvard and mentioned that he was writing a book on molecular orbital theory. When I told him about the alkali dimer case, he refused to believe it, saying, "If that's true, I'll quit theoretical chemistry." I sent him the relevant papers, and he did forthwith abandon chemistry.

After completing his Ph.D. work in less than three years, Yuan stayed on with Mahan as a postdoctoral fellow. Bruce had decided to do crossed beam studies of ion−molecule reactions, so Yuan and Ron Gentry undertook to construct an apparatus. Within a year, they had designed and built a state-of-the-art machine and obtained a complete contour map of the distribution of products in velocity and angle from the $N_2^+ + H_2$ reeaction. In 1966, that was a landmark accomplishment, and it launched a very fruitful research program.

In this work, Yuan also equipped himself to become an experimental virtuoso. After a few sessions with design engineers at the Radiation Lab, he asked to be taught how to do the drawings, to specify welding sequences, the precision of bolt holes, etc. In only a week of intense study, Yuan mastered such matters; thereafter, he did all the drawings and detail work himself. He also markedly enhanced his English. For that he credits Bruce's insistance that he speak in complete sentences as well as the opportunity, since the group was small and his work so productive, to give many seminar reports.

Hopeful at Harvard. Yuan joined my group at Harvard in February of 1967 as a postdoctoral fellow. Only many years later did I learn that his chief aim was to gain some experience doing theoretical work; he felt, rightly, that he was already adept with experiments and apparatus building. But Yuan was too shy to tell me so and did not demur when I suggested he might want to consider two experimental projects. One was a crossed beam study of reactions of hydrogen atoms with alkali dimer molecules, which he undertook in collaboration with a graduate student, Robert Gordon. That did not require new apparatus, and as expected, the results nicely exemplified dynamical features arising from the special properties of the dimers and their ions that Yuan had established in his thesis work. However, Robert and Yuan had some special adventures doing the experiments. They used a deflecting electromagnet to sort the small fraction of dimers out from the parent alkali atom beam. When a tube carrying cooling water for the magnet sprang a leak, their vacuum chamber filled with water; yet, after cleaning up the mess, they found that the apparatus actually performed better.

Far more ambitious was the other project, construction of an apparatus to take us "beyond the alkali age". During the early years in which molecular beam chemistry dealt solely with alkali reactions, skeptics discounted them as an eccentric, unrepresentative family, despite the instructive variety of dynamics found. An unduly pessimistic view of prospects for beam studies of nonalkali reactions was also prevalent. This came from attempts to use mass spectrometric detection that failed to reduce sufficiently the interfering background in the electron bombardment region.

Yuan devoted his afternoons for several months (while working with Gordon before lunch and after dinner) to design calculations and draft plans for the new apparatus, which we named "Hope". Teamed with Yuan were two beginning graduate students, Pierre LeBreton and Doug McDonald, who likewise had other projects too. Also involved in the design as well as construction were George Pisiello and other machinists in our small but excellent Departmental Shop. It was the first project of such magnitude entrusted to the Shop, which responded with alacrity. The construction of various parts proceeded right behind their design, and for several items Yuan cheerfully adjusted plans for subsequent components to compensate for fabrication errors such as misplaced bolt holes. Everyone worked with extraordinarly zeal, inspired by a sense of mission and great confidence in Yuan's skill and judgement. As each of the myriad design questions was settled, we all relished his verdict: "Should be all right."

His verdict did always prove correct (even if not a complete sentence); indeed, for several years after Yuan left, we had his photo mounted on the apparatus with "Should be all right" as the caption. The building of Hope took only 9 months, from the first plans to the first experimental run, shortly before Chirstmas of 1967. For that first experiment we chose the Cl + Br_2 reaction and immediately obtained data of excellent quality that revealed striking dynamical features. It was an exhilerating portent for a host of studies that followed, enabled by Hope and similar machines in other laboratories, many of them built by Yuan or patterned after his designs. Figure 1 shows Yuan with one of this "all right" machines.

The birth of Hope, with such a brief gestation, was startling and properly credited to exceptional talent, hard work, and verve. But another crucial aspect deserves emphasis. Despite several attempts, I had been unable to obtain funding to build such a major apparatus. Then, as now, instrumentation grants for chemists went almost solely for "departmental" apparatus, to be used by several research groups and purchased rather than built from scratch. Fortunately, Ron Vanelli, Director of the Chemical Laboratories, had faith in our young team and allowed us to build Hope by simply running a big deficit in my research account ($80 K in 1967 dollars). Today, something equivalent would be impossible or illegal. Yuan recalls that Vanelli frequently came by to check on how the project was developing, saying, "if it doesn't work, you'll have to shovel a lot of snow."

Convincing at Chicago. Yuan and the results obtained with Hope made a great impression at a Gordon Conference in June, 1968. He was soon invited to join the faculty of the University of Chicago, which he did in October. There he likewise was blessed with fine support and attracted excellent students; among them were John Parson, his first graduate student, and Peter Siska, his first postdoctoral fellow, both from Harvard. Soon Yuan had a new apparatus going and began publishing work of remarkable incisiveness and scope. This included definitive studies of the elastic scattering of pairs of noble gas atoms, with fully resolved quantum interference structure. That work enabled determination with unprecedented accuracy of intermolecular potentials that are now the standard for assessing other experiments and theoretical results. Among other superb experiments were studies of collision-induced dissociation of alkali halides, scattering of metastable rare gase atoms, and the first crossed beam studies of reactions of fluorine atoms with hydrogen molecules and with unsaturated hydrocarbons. All these provided prototype results that stimulated and challenged theoretical analysis.

Booming at Berkeley. Yuan returned to Berkeley in 1974 and promptly expanded his research to include primary photochemical processes and spectroscopy of ionic and molecular clusters, as well as many further studies of reaction dynamics in crossed molecular beams. His laboratory became a veritable cornocopia for chemical physics, pouring forth a broad and

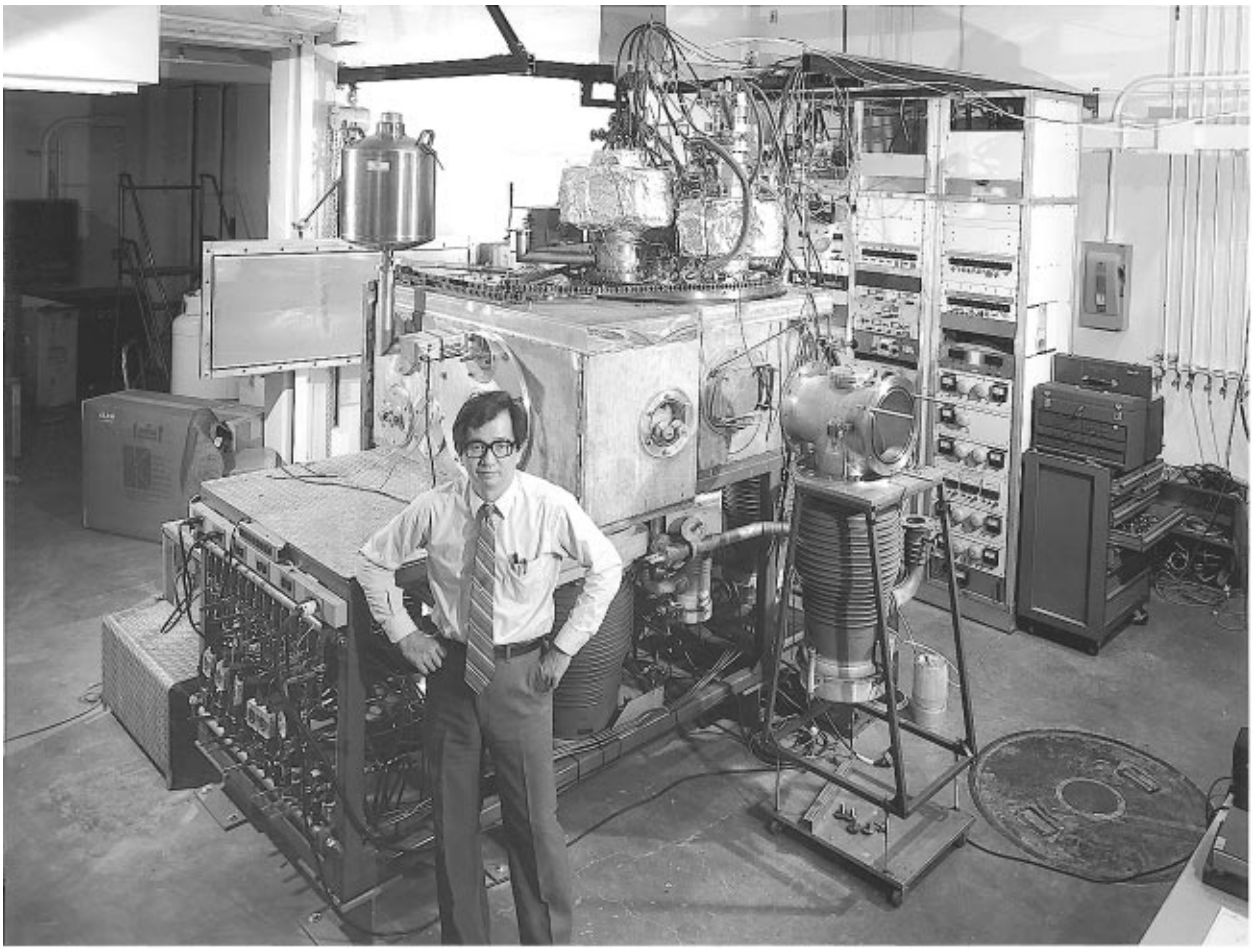

Figure 1. Yuan T. Lee with a typical molecular beam apparatus in his laboratory at Berkeley. (Photograph by Ernest Orlando, Lawrence Berkeley National Laboratory.)

sparkling stream of new methods, path-breaking experimental findings, and conceptual insights.

Among exemplary contributions[4] are (1) resolution of the complete state-to-state product distributions and dynamical resonances in the $F + H_2$ reaction; (2) identification of primary steps in reactions of radicals with unsaturated hydrocarbons; (3) the dynamics of endothermic substitution reactions; (4) the dependence of chemical reactivity of electronically excited atoms on the alignment of excited orbitals; (5) dynamics of photofragmentation of many polyatomic molecules; (6) intramolecular energy transfer in chemically activated or locally excited molecules; (7) the energetics of free radicals important in combustion processes; (8) infrared absorption spectra of carbonium ions and hydrated hydronium ions; (9) bond-selective photodissociation governed by specific electronic excitation; (10) binding energies of molecular ions; (11) highly accurate proton affinities of hydrogen halides, water, and ammonia; and (12) analysis of facile reactions of carbon atoms with unsaturated hydrocarbons, developing evidence for the importance of such reactions in some circumstellar envelopes. The list could be much longer, but already its scope includes terrestrial, marine, atrmospheric, and astrophysical chemistry; these dozen labors would more than suffice to exhaust Hercules.

In 1994, Yuan retired from his position as University Professor at Berkeley and became President of the Academia Sinica in Taipei. There he has devoted much effort to fostering educational reform while also overseeing 22 research institutes. Among them is the Institute of Atomic and Molecular Sciences. Yuan had a seminal role in its creation in 1983 and now is setting up his own laboratory there. His group at Berkeley is still quite active and productive, however, and he continues to serve as a Graduate Professor.

The Lee group work has been amply reviewed elsewhere.[4] Here I will emphasize an aspect that has much to do with its outstanding qualities. Beyond his exceptional ability and dedication, Yuan has a sure sense of what might be termed scientific style or taste. In his choice of problems and strategy, as in his design of apparatus, Yuan's judgement is astute and accurate. He devises experiments that get at issues of leading theoretical interest or are likely to create such issues. When Yuan defines a question or selects a system amenable to detailed study, his co-workers know that, formidable as the project may appear at the start, it will come out "all right". Yuan will have carefully looked into all relevant aspects, anticipated the key difficulties, and found ways to avoid or overcome them. Furthermore, his colleagues know that the results will contribute significantly to shaping perspectives on some fundamental aspect of chemistry.

Impressed as they are by Yuan's talent and committment to science, his many able students and co-workers also greatly admire his character and personality. Manifest in his mentoring and teaching are genuine concern for his charges, a keen perception of their needs, good humor, and luminous integrity. Although his demeanor is always modest, he often fairly glows with pleasure and pride in the achievements of his laboratory and his scientific progeny. Also characteristic is his physical stamina. Yuan is in great demand to lecture on his research and to serve on editorial boards and advisory committees, yet he manages to fulfill myriad responsibilities with élan.

As well as sharing vicariously in the exhilaration of his work, I've had many opportunties over the years to hear talks by Yuan, always exciting. In particular, I have enjoyed witnessing the evolution and elaboration of his repertoire of baseball and other sports analogies for chemical dynamics. However, as pointed out to me by several of his recent colleagues, when human relations come up, Yuan habitually employs chemical analogies. For instance, when informed of a romantic involvement in his group, he is likely to say, "I hope it will turn out to be exothermic!"

The Symposium on Reaction Dynamics held in Taiwan to celebrate Yuan's 60th birthday came precisely 10 years after another memorable encounter, in Stockholm. Although the pomp of the Nobel festivities is well known, the most exothermic and dynamic activities are not. For instance, late in the week, the Student Union hosts a party during which Laureates who are willing are inducted into the "Sacred Order of the Ever-Smiling and Jumping Frog". This requires the inductees to hop about for a considerable time, croaking like a frog. John Polanyi managed to do it with a semblance of dignity, I flopped about awkwardly, whereas Yuan performed with exceptional agility. It struck me that at a 60th birthday celebration, the honorand ought similarly to imitate the creature of his birthyear, thereby welcoming with gusto a new cycle of the zodiac. Thus I suggested that Yuan might want to consider dashing about while squeaking like a mouse. This time, however, he did demur.

Underlying both the birthday and Nobel celebrations is recognition of the abiding value of kinship. Whether among a biological family or a scientific clan with shared aims, it transcends generations and geography. Yuan and his wife, Bernice Chinli Wu, met in elementary school; they have three children, Ted, Sidney, and Charlotte, and many siblings and relatives, both in Taiwan and other parts of the world. Yuan's scientific siblings and progeny are still more widespread, but engender the same kind of mutual appreciation and support. Yuan has written[1] about his debt to an ancestral generation of "most generous and caring scientists". The deep loyalty he has shown to his homeland is in harmony with his devotion to science and learning.

In a recent conversation, Yuan surprised me by confessing that when Hope was first operated, 30 years ago, he was much less sure that it would work as intended than the rest of us were. Even when he had been offered the appointment at Chicago, he had doubts that he could measure up to expectations. He felt that his success owed a lot to the total confidence and trust in him that I and others he worked with had shown. Of course, I told him it had never occurred to me that he could harbor such doubts, when his exceptional qualities were so obvious to everybody. Yet I have met many young people who suffer from a lack of confidence commensurate with their ability. With Yuan, I hope that such neophytes will be heartened to know the syndrome can afflict even an extraordinary young scientist; likewise, mentors need to be aware how important it can be to bestow confidence.

At the birthday banquet, the guests all received from Yuan a cup signifying his thirst for learning. It is inscribed in his calligraphy with Chinese characters that read: "Learning is a lifelong endeavour". As a concluding toast to him, I quote a poem that resonates with his motto. The poem[5] was written about a century ago by Maria Sklodowsky, later to become renowned as Marie Curie, but then an earnest young student living in a small 6th floor room in Paris:

Yet she has joy in what she knows
For in her lonely cell she finds
Rich air in which the spirit grows
Inspired by the keenest minds.
Ideals flood this tiny room;
They led her to this foreign land,
They urge her to pursue the truth
And seek the light that's close at hand.
It is the light she longs to find,
When she delights in learning more.
Her world is learning; it defines
The destiny she's reaching for.

Maria's poem is also an apt tribute to Yuan Tseh Lee, a half-century after her story inspired him to pursue his destiny in science.

References and Notes

(1) Lee, Y. T. *Les Prix Nobel en 1986*; Nobel Foundation: Stockholm, 1987; pp 166−206.

(2) This paper is mostly based on recent conversations with Yuan and on my speech at the Y. T. Lee Banquet held on December 10, 1996, in the Grand Formosa Regent Hotel in Taipei. The scene included a giant ice sculpture featuring the number 60, an orchestra playing traditional instruments, and 350 guests who had enjoyed an 18-course dinner. Also worthy of mention was a timely front-page photo in the day's newspaper; the accompanying story described an argument between two taxicab drivers that culminated in a dramatic head-on collision between their vehicles.

(3) At the Y. T. Lee Banquet, I gave Yuan two birthday presents: a softball (made in China) autographed by more than 100 colleagues, and a copy of the new biography by Susan Quinn, *Marie Curie*; Addison-Wesley: New York, 1995.

(4) References to the research literature are omitted; they may be readily found from the complete listing of Lee group papers included in this issue.

(5) The poem, originally in Polish, was versified in English by Jan Schreiber; it is reprinted with permission of Simon & Schuster from Quinn, S. *Marie Curie, A Life*; Addison-Wesley: New York, 1995; p 92.